



**CHEMISTRY**  
**HIGHER LEVEL**  
**PAPER 3**

Tuesday 19 May 2009 (morning)

1 hour 15 minutes

Candidate session number

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**INSTRUCTIONS TO CANDIDATES**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.



**Option A — Modern analytical chemistry**

**A1.** (a) State **two** reasons for using analytical techniques. [2]

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(b) Explain what occurs at a molecular level during the absorption of infrared (IR) radiation by the sulfur dioxide molecule, SO<sub>2</sub>. [3]

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(c) Describe the operating principles of a double-beam IR spectrometer. [4]

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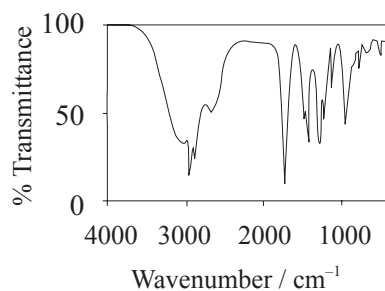
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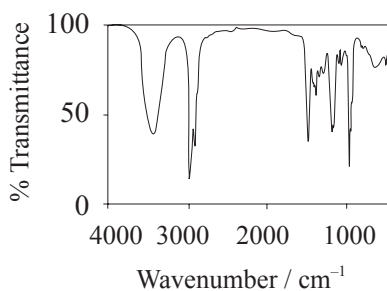


(Question A1 continued)

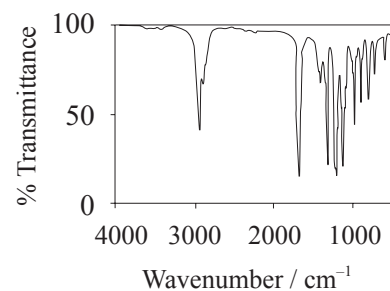
(d) Consider the IR spectra of the following three compounds.



I



II



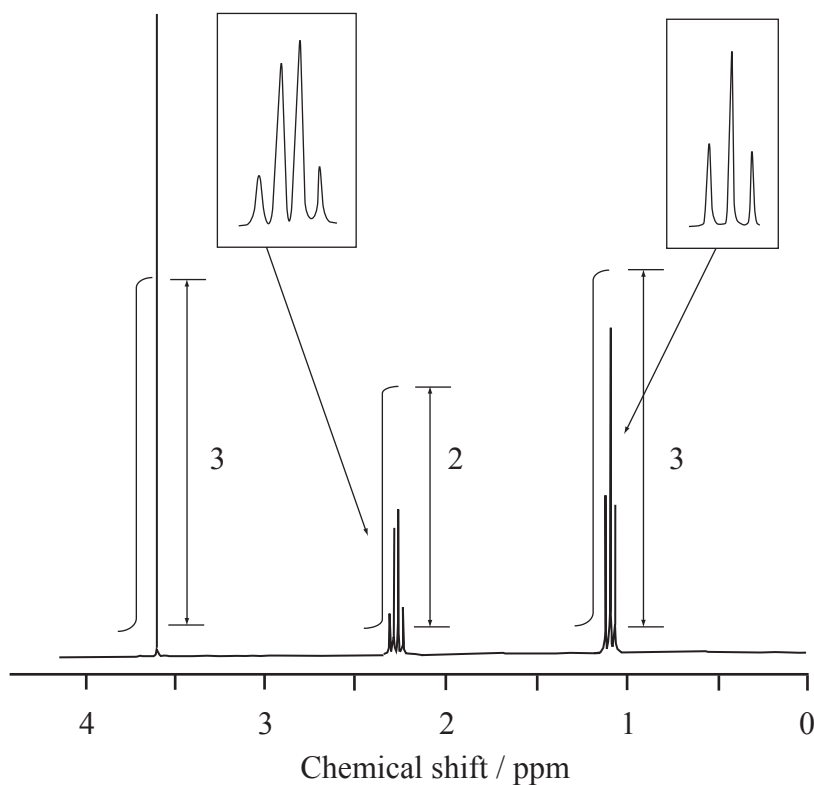
III

Determine which IR spectrum corresponds to each compound A, B and C. Explain your reasoning. IR data can be found in Table 17 of the Data Booklet.

[5]

Compound	Spectrum	Reason
A	....	..... ..... .....
B	....	..... ..... .....
C	....	..... ..... .....

- A2.** (a) A feature of some  $^1\text{H}$  NMR spectra is the electron-withdrawing effect of electronegative atoms. These atoms cause nearby protons to produce peaks at higher chemical shift values, often in the range 2.5 to 4.5 ppm. Consider the  $^1\text{H}$  NMR spectrum of an unknown compound, D, which has a molecular formula  $\text{C}_4\text{H}_8\text{O}_2$  and is known to have an absorption in its IR spectrum corresponding to a  $\text{C}=\text{O}$  absorption.



Use this information and the values in Table 18 of the Data Booklet to deduce the structure of D.

[4]

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*(Question A2 continued)*

(b) Outline how NMR is used in body scanners.

[2]

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**A3.** (a) The wavelength of colour absorbed by a transition metal complex can be explained in terms of the splitting of the d orbitals in the metal ion.

(i) For the complex,  $[\text{Ni}(\text{NH}_3)_6]\text{Cl}_2$ , draw a diagram showing the splitting of the d orbitals. [2]

(ii) Outline why colour depends on the oxidation state of the transition metal. [1]

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(iii) The complex  $[\text{Ni}(\text{NH}_3)_6]\text{Cl}_2$  is purple. Predict the colour of the  $[\text{Ni}(\text{H}_2\text{O})_6]\text{Cl}_2$  complex and explain your answer. [2]

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**Option B — Human biochemistry**

**B1.** Myoglobin is a globular protein found in the muscle tissue and is formed from 2-amino acids.

- (a) State the name of the bond or interaction that is responsible for linking the amino acids together in the primary structure. [1]

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- (b) State the name of the bond or interaction that is responsible for the secondary structure. [1]

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- (c) State **two** of the bonds or interactions responsible for the 3D shape of myoglobin. [2]

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**B2.** Many lipids are found in the human body. One type of lipid is a triglyceride.

- (a) The formulas of some fatty acids are shown in Table 22 of the Data Booklet. State the equation for the reaction between glycerol and stearic acid to form a triglyceride. [3]

- (b) To measure the degree of unsaturation of a lipid the iodine number can be calculated.

- (i) Define the term *iodine number*. [1]

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- (ii) Calculate the iodine number of linoleic acid.



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- (c) Steroids are another class of lipid found in the body. Cholesterol is a steroid. Distinguish between *HDL* and *LDL* cholesterol. [2]

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**B3.** Steroids can act as hormones in the human body.

- (a) The structures of some hormones can be found in Table 21 of the Data Booklet. State the name of a functional group that is present in both progesterone and testosterone but not present in estradiol. [1]

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- (b) Describe how oral contraceptives function in the female body. [2]

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**B4.** Pepsin is an enzyme, found in the stomach, that speeds up the breakdown of proteins. Iron is used to speed up the production of ammonia in the Haber process.

- (a) Describe the characteristics of an enzyme such as pepsin, and compare its catalytic behaviour to an inorganic catalyst such as iron. [4]

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- (b) Enzymes are affected by inhibitors. Lead ions are a non-competitive inhibitor, they have been linked to impaired mental functioning. Ritonavir<sup>®</sup> is a drug used to treat HIV and acts as a competitive inhibitor. Compare the action of lead ions and Ritonavir<sup>®</sup> on enzymes, and how they affect the initial rate of reaction of the enzyme with its substrate and the values of  $K_m$  and  $V_{max}$ . [5]

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**Option C — Chemistry in industry and technology**

**C1.** In the last 15 years several Nobel prizes have been awarded in the area of nanotechnology, from the development of the scanning probe microscope, to the discovery of fullerenes. By 2015 nanotechnology could employ two million workers worldwide.

- (a) After the discovery of  $C_{60}$ , chemists discovered carbon nanotubes. Describe the structure and properties of carbon nanotubes. [4]

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- (b) Nanotechnology could provide new solutions for developing countries where basic services such as good health care, education, safe drinking water and reliable energy are often lacking. Discuss some of the potential risks associated with developing nanotechnology. [4]

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**C2.** Fuel cells may be twice as efficient as the internal combustion engine. Although fuel cells are not yet in widespread use, NASA has used a basic hydrogen-oxygen fuel cell as the energy source for space vehicles.

- (a) State the half-equations occurring at each electrode in the hydrogen-oxygen fuel cell in an alkaline medium. [2]

(+) Cathode:

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(–) Anode:

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- (b) Describe the composition of the electrodes and state the overall cell equation of the nickel-cadmium battery. [3]

(+) Cathode:

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(–) Anode:

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Cell equation:

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- (c) Compare a fuel cell and a lead-acid battery, with respect to possible concerns about pollution of the environment. [2]

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- (d) State with a reason whether a solid fuel could be used in a fuel cell. [1]

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- C3.** (a) Distinguish between *thermotropic* and *lyotropic* liquid crystals. [2]

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- (b) Kevlar<sup>®</sup> is a lyotropic liquid crystal. Explain the strength of Kevlar<sup>®</sup> and its solubility in concentrated sulfuric acid. [2]

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- (c) Describe the use of silicon in photovoltaic cells. Include the following in your description:
- why pure silicon is a better conductor than non-metals such as sulfur and phosphorus
  - how a p-type semiconductor made from silicon is different from pure silicon
  - how sunlight interacts with semiconductors.
- [5]

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**Option D — Medicines and drugs**

**D1.** Analgesics are used to relieve pain in the body. Aspirin and paracetamol (acetaminophen) are both mild analgesics.

- (a) Discuss the advantages of using aspirin instead of paracetamol. [2]

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- (b) Compare how mild and strong analgesics relieve pain in the body. [2]

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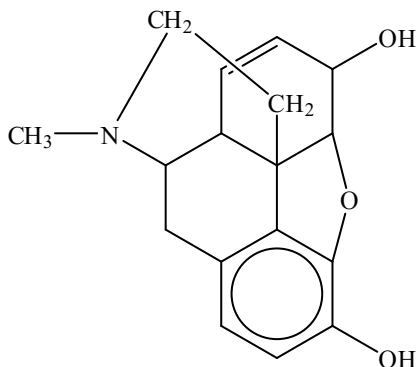
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- (c) The structures of the strong analgesics morphine and heroin (diamorphine) can be found in Table 20 of the Data Booklet.

- (i) Identify the amine functional group in the morphine molecule below by drawing a ring around it. [1]



- (ii) Classify the type of amine present in morphine. [1]

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- (iii) State the name of the functional group found in heroin but not in morphine. [1]

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*(This question continues on the following page)*

*(Question D1 continued)*

- (iv) Explain the increased potency of heroin (diamorphine) compared to morphine. [2]

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**D2.** Medicines and drugs alter the physiological state of the body including consciousness and coordination.

(a) State **one** other effect of medicines and drugs on the body. [1]

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(b) Explain the meaning of the following terms:

(i) *therapeutic window*. [1]

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(ii) *tolerance*. [1]

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*(Question D2 continued)*

- (c) In recent years there have been significant advances in drug design, mainly due to the techniques of combinatorial chemistry and parallel synthesis. Discuss the use of these techniques, with reference to:

- (i) the advantage of the techniques compared to previous methods. [1]

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- (ii) the methods used. [3]

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- (iii) the difference between combinatorial chemistry and parallel synthesis. [1]

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**D3.** Ethanol is a depressant that is widely consumed in many societies. When consumed excessively it has a major impact on families and society as a whole. Other depressants such as diazepam (Valium<sup>®</sup>) may be prescribed by a doctor.

- (a) Describe the effect on the individual of consuming depressants at moderate and high doses. [2]

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- (b) One problem associated with ethanol consumption is an increased risk of traffic accidents. Police in many countries use a breathalyser to test drivers. The breathalyser contains potassium dichromate(VI).

- (i) Describe the colour change of potassium dichromate(VI) when it reacts with ethanol. [1]

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- (ii) State with a reason whether chromium in potassium dichromate(VI) is oxidised or reduced by ethanol. [1]

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- D4.** The structures of mescaline and lysergic acid diethylamide (LSD) are in Table 20 of the Data Booklet. Describe **two** effects of taking mescaline on the human body and discuss the structural similarities between mescaline and LSD that lead to some of their similar properties.

[4]

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**Option E — Environmental chemistry**

**E1.** The greenhouse effect maintains the earth's temperature, which makes the planet habitable. However, over the last 100 years the average temperature of the earth has increased by almost 1°C. Most climate scientists believe this warming is due to increased levels of greenhouse gases in the atmosphere.

- (a) Two of the major greenhouse gases in the atmosphere are methane and carbon dioxide. State **two** other major greenhouse gases. [2]

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- (b) Discuss which **two** gases from the four gases in part (a) are the most significant for global warming. [2]

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- (c) Discuss **two** effects of global warming. [2]

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**E2.** Water purity is often assessed by reference to its oxygen content.

- (a) Outline the meaning of the term *biochemical oxygen demand* (BOD). [2]

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- (b) Describe how the dissolved oxygen concentration in a river would decrease if

- (i) a car factory releases warm water into the river after using it for cooling. [1]

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- (ii) a farmer puts large quantities of a fertilizer on a field next to the river. [1]

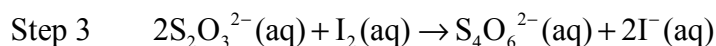
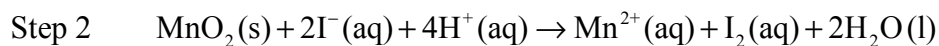
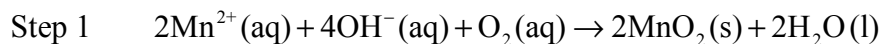
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(Question E2 continued)

- (c) The Winkler method uses redox reactions to find the concentration of oxygen in water. 100 cm<sup>3</sup> of water was taken from a river and analysed using this method. The reactions taking place are summarized below.



- (i) State what happened to the O<sub>2</sub> in step 1 in terms of electrons. [1]

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- (ii) State the change in oxidation number for manganese in step 2. [1]

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- (iii) 0.0002 moles of I<sup>−</sup> were formed in step 3. Calculate the amount, in moles, of oxygen, O<sub>2</sub>, dissolved in water. [1]

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**E3.** Waste water can contain metal ions such as chromium. Chromium ions can cause damage to the liver and kidneys. Chromium ions can be removed from water by chemical precipitation using hydroxide ions.

- (a) Assuming chromium is present as  $\text{Cr}^{3+}$ , state an equation for its reaction with hydroxide ions, include state symbols. [2]

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- (b) State an expression for the solubility product constant,  $K_{\text{sp}}$ , for chromium(III) hydroxide. [1]

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- (c) The solubility product of chromium(III) hydroxide is  $1.00 \times 10^{-33} \text{ mol}^4 \text{ dm}^{-12}$  at 298 K. Calculate the concentration, in  $\text{mol dm}^{-3}$ , of  $\text{Cr}^{3+}$  in the solution, when chromium(III) hydroxide is precipitated. [2]

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**E4.** The ozone in the stratosphere protects us from harmful UV radiation. Above Australia there is an area of decreased ozone concentration that has led to an increase in the incidence of some skin cancers.

- (a) Explain how the dissociation of  $O_2$  and  $O_3$  is dependent on the wavelength of light. [2]

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- (b) Use equations to describe the mechanism of ozone depletion catalysed by the  $CCl_2F_2$  molecule. [3]

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- (c) Discuss the advantages and disadvantages of using hydrocarbons in place of CFCs. [2]

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**Option F — Food chemistry**

**F1.** Artificial food colourants have recently been linked to increased hyperactivity in children. Many foods are colourful because of the natural pigments they contain.

(a) Explain why naturally-occurring pigments are coloured. [1]

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(b) State the class of pigments that give cranberries and strawberries their colour. [1]

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(c) (i) State the class of pigments that give carrots and tomatoes their colour. [1]

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(ii) Outline why this class of pigment is susceptible to oxidation, and the effect of oxidation on this pigment. [2]

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**F2.** Antioxidants occur naturally and are often added to extend the shelf life of our food.

- (a) Define the term *antioxidant*. [1]

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- (b) Explain the differences between the three main types of antioxidant. Include in your answer:

- an example of each type of antioxidant
- a brief account of how it works. [6]

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- (c) Table 22 in the Data Booklet shows the structures of some antioxidants. Determine the **two** functional groups that are found in all of these synthetic antioxidants: 2-*tert*-butyl-4-hydroxyanisole (2-BHA), 3-*tert*-butyl-4-hydroxyanisole (3-BHA) and 3,5-di-*tert*-butyl-4-hydroxytoluene (BHT). [2]

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*(This question continues on the following page)*

(Question F2 continued)

- (d) Describe the step by step mechanism for the free radical reaction that causes an oily fish such as mackerel to become rancid. Include the name of each step and an equation for each step in your answer.

[6]

Step 1:

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Step 2:

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Step 3:

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- F3.** Genetically modified (GM) foods are now widely available, although in some countries environmental groups are campaigning against them. Define the term *genetically modified food* and discuss the benefits and concerns of using GM foods.

[5]

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**Option G — Further organic chemistry**

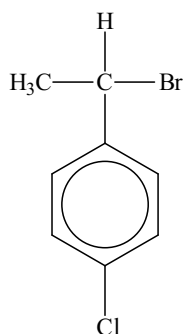
**G1.** Benzene,  $\text{C}_6\text{H}_6$ , undergoes electrophilic substitution reactions in order to synthesize other compounds.

- (a) (i) Describe, using an equation, the formation of the electrophile in the nitration of benzene. [2]
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- (ii) Describe the stepwise mechanism for the reaction of benzene with ethanoyl chloride,  $\text{CH}_3\text{COCl}$  in the presence of aluminium chloride, using curly arrows to show the movement of electron pairs. [3]

*(This question continues on the following page)*

(Question G1 continued)

(iii) Chlorobenzene can be converted in two steps into the compound below.



State the reagents and conditions required for each step and state the structure of the compound formed after the first step. [3]

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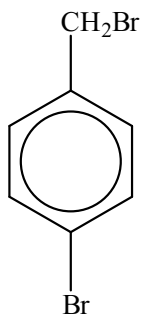
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(Question G1 continued)

- (b) (i) Methylbenzene can be converted in two steps into the compound below.



State the reagents and conditions required for each step.

[2]

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- (ii) Deduce the formula of the product when the compound above reacts with hydroxide ions. Explain your answer.

[2]

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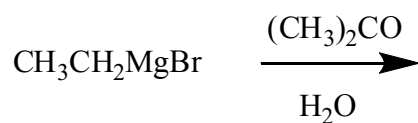
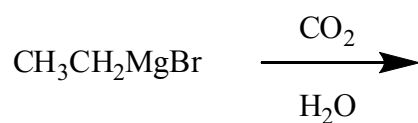


**G2.** (a) Magnesium is a very electropositive metal which can be used in the formation of Grignard reagents.

- (i) State the product when bromomethane and magnesium react together in a non-polar solvent. [1]

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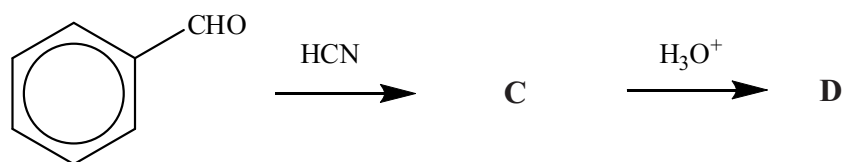
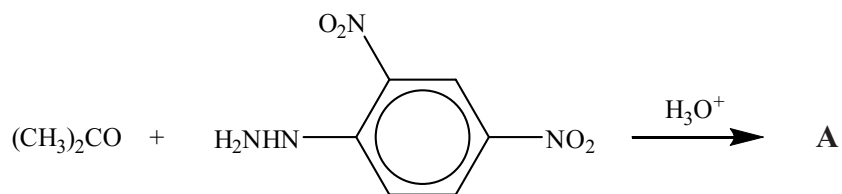
- (ii) Draw the structural formulas of the organic products formed in the following reactions. [2]



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(Question G2 continued)

- (b) Draw the structural formulas of the organic products, **A–D**, formed in the following reactions. [4]



**A:**

**B:**

**C:**

**D:**

(This question continues on the following page)

*(Question G2 continued)*

- (c) The product, **B**, can exist in two forms. Draw three-dimensional representations of both structures and suggest a reason for their existence.

[2]

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- G3.** Elimination reactions are common for tertiary alcohols. State the organic product formed in this acid-catalysed reaction and describe the mechanism using curly arrows to show the movement of electron pairs. [4]

